CONSTRUCTAL TREE NETWORK CHANNELS AS FLUID DISTRIBUTORS IN POLYMER ELECTROLYTE FUEL CELLS

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Constructal tree-like channel networks developed by Bejan and his co-workers in recent years are investigated as a fuel cell fluid distribution concept, which also optimizes the shape of polymer electrolyte fuel cells. To perform quantitative calculations based on this concept, a one-dimensional model, accounting for oxygen consumption in the feed channel, oxygen mass transfer between the channel and the backing layer, and oxygen mass transfer through the backing layer to the catalyst layer, is used to predict the polarization curve of a so constructed polymer electrolyte fuel cell. Pressure drop and pumping power required for the fluid circulation is estimated. Multiobjective genetic search is performed to maximize the net power density with respect to constructal parameters and operating conditions, leading to the optimized tree network. Entropy generation minimization subject to physical constraints that are responsible for the irreversible operation of a device is the method of modeling and optimization of real devices for which the thermodynamic imperfection is due to heat transfer, mass transfer, and fluid flow irreversibilities.

The resulting “double staircase” shape of the fuel cells differs from the traditional rectangular shape while maintaining simplicity and it is determined based on the functionality of the flow distribution system. It is found that the tree network fluid distribution system allows for substantially increased electric and net power densities compared to the traditional non-bifurcating systems, due to reduced mass transfer losses in the lateral direction in the backing layer, reduced mass transfer losses between the channels and the channel/backing layer interface, and reduced pumping power. In addition to the higher electric power density, the tree network system can also provide substantially reduced pressure drop and pumping power, leading to a higher net power density. This aspect becomes important for low diameter channels and high mass flow rates which both are required for high electric current densities. The influence of a host of operating condition parameters is discussed. An optimized tree network which provides a maximum net power density is then derived by means of a genetic optimization algorithm. As an example, a tree network fluid distributor with only six branching levels already allows for a 24 % improvement in net power density under the imposed constraints and operating conditions, compared to a traditional non-bifurcating serpentine channel. Due to their intrinsic advantage with respect to both mass transfer and pressure drop, constructal tree networks have the potential to significantly improve the performance of polymer electrolyte fuel cells at different length scales.

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